Protura and Diplura succession on chemical factory deposits

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Primary succession of Protura and Diplura was studied on deposits of a former chemical factory at Petrovice u Karviné, NE Moravia, Czech Republic, in 1978-1979, 1993 and in 2002-2004. Chemically loaded deposits were 15, 25 and 60 years old in 1979 and a primary succession without plant re-cultivation took place there. The succession was delayed on small humps and slopes where the deposited substrate was covered by terrestrial algae, lichens and mosses. Protura did not enter the primary succession before a moss cover occurred on the 15 years old heap and they were represented only by *Acerentulus traegardhi*. Three species of Protura were established in the 20 years old grass-covered stage as well as on the 49 years old heap. They occurred in low densities up to the 74 years old stage (and older), in which a proturan community of 4 – 6 species was established (*Acerentulus traegardhi, A. exiguus, Gracilentulus gracilis, Proturentomon* cf. *noseki, Eosentomon gramineum* and *E. mixtum*) and reached a density of 5 400 – 10 200 ind.m^{-2}. Diplura entered the succession in the stage of invading grass tufts on the 20 years old heap and two species were recorded in this early stage of succession, *Campodea suensoni* and *C. silvestri*, but only the first one was recorded later and in the most developed stage. The presence of the proturan community and the occurrence of only one dipluran species in the succession series are discussed in connection with the humus form and humus layer development.

Keywords: Protura, Diplura, chemical factory deposits, primary succession, humus form, soil microstructure.

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Introduction

Primary succession of Collembola and humus development was studied on deposits of a former factory producing nitric, sulphuric, and muratic acids and soda at Petrovice u Karviné, NE Moravia, Czech Republic, in 1978 – 1979, in 2002 - 2004 (Rusek, 2004, 2005b) and less extensively in the time between these periods (1993). Pauropoda, Symphyla, Protura and Diplura were present in the substrate and humus samples used for collembolan community succession studies, too. The mentioned groups of soil meso- (Pauropoda, Protura) and macrofauna (Symphyla, Diplura) belong to the euedaphic soil fauna and they are highly susceptible to soil dessication. Both groups of the microarthropod mesofauna are specialized mycorrhizal fungi feeders (Hüther, 1959; Sturm, 1959). There are almost no data in the literature about Protura and Diplura occurrence in soil succession series. Only Kubíková and Rusek (1976) mentioned Protura in their study of xerothermic rendzina development and Bode (1973, 1975) reported Protura and Diplura in the succession of the re-cultivated soils of brown coal spoil heaps in Germany. The participation of Pauropoda and Symphyla in the succession on deposits of a former factory at Petrovice u Karviné is described and discussed in a separate contribution (Rusek, 2005a).

The goals of this contribution are:

1. To describe and characterize the occurrence of different species of Protura and Diplura in the succession series on chemically loaded deposits of a former chemical factory;
2. To relate the occurrence of different Protura and Diplura species with the plant cover and humus form successive development;
3. To compare and discuss the Protura and Diplura succession with the development of xerothermic rendzina soils (Kubíková and Rusek, 1976).

Study sites and methods

The deposits from a former chemical factory producing nitric, sulphuric, and hydrofluoric acids and soda are located at Petrovice u Karviné, NE Moravia, Czech Republic (49° 53' N, 18° 32' E). Chemically loaded deposits were 15, 25 and 60 years old in 1979 and a primary succession without plant re-cultivation took place there. The succession was delayed on small deposit humps and slopes where the substrate was covered by terrestrial algae, lichens and/or mosses (Fig. 1). The 15 years old heap (Fig. 2) was covered by mosses and invading tufts of *Holcus lanatus* and *Calamagrostis epigeios*, the 25 years old stage (Fig. 3) was covered by the following shrubs, trees and understory plants: *Salix caprea, Betula*

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verrucosa, *Populus tremula*, *Crataegus monogyna*, *Holcus lanatus*, *Poa pratensis angustifolia*, *Parthenocissus quinquefolia*, *Equisetum arvense*, *Dryopteris austriaca*, *Epilobium montanum*, and others. The 60 years old heap was covered by the following trees, shrubs and understory plants (on large patches the soil surface was covered only by litter, without understory plants): *Salix caprea*, *Populus tremula*, *Quercus robur*, *Q. petraea*, *Tilia cordata*, *Carpinus betulus*, *Betula verrucosa*, *Acer platanoides*, *Viburnum opulus*, *Holcus lanatus*, *Calamagrostis epigeos*, and others. The 60 years old white substrate heap (pH 7.4) contained up to 73% of $CaCO_3$ and other remnants of powdery consistence from the soda production, the remaining red heaps (pH 4.8) were composed of iron pyrite remnants and grinded rests of the pyrite bedrock from the sulphuric acid production containing more than 50% of Fe_2O_3. A raw humus layer of different thickness covered the substrate up to the 15 years old heap where a microarthropod raw humus form started to develop. On the 20 years old red heap with *Poa pratensis* and *Holcus molis* the humus form changed to a raw humus-moder and reached 3 - 5 cm thickness on the 25 years old red deposit heap. It changed during the next 24 years of succession to a moder-raw humus form on the 49 years old red heap. The humus development was more favourable on the red substrate heap than on white substrate, where the humus form reached the raw humus-moder stage during 60 years of succession. This humus form developed during the following 24 years of succession to a moder in the upper part of the humus horizon and to a transition to moder-raw humus in the deeper layer (up to 7.5 – 9 cm) on the 84 years old white substrate heap (Rusek, 2005b). Beech and oak forests are climax succession stages in the immediate and wider vicinity of the heaps (e.g. in Petrovice u Karviné, Bohumín, Moravskoslezské Beskydy Mountains). The plant cover succession on the heaps tends to develop to a climax *Tilio-Quercetum* forest (Rusek, 2004).

Ten random samples, each 10 cm^2 in soil surface area and 1,97 in deep, were taken from each succession stage at each locality and extracted in Tullgren funnels. Samples were taken on April 29, 1978 (D608, D611), July 11, 1978 (D589-D591), August 7, 1993 (B118, B122), March 17, 1979 (D598) and October 9, 2003 (E165-E167). Sample and site characteristics are shown in Table 1. Extracted material of microarthropods was preserved in 96% ethanol. All Protura and Diplura were mounted for identification on permanent slides (Rusek, 1975a) and counted. The qualitative and quantitative data are related to the succession age, humus form and plant cover.

Results

Six species of Protura [*Acerentulus exiguus* Condé, 1952, *A. traegardhi* Ionescu, 1937, *Gracilentulus gracilis* (Berlese, 1908), *Proturentomon* cf. *noseki* Rusek, 1975, *Eosentomon gramineum* Szeptycki, 1986 and *E. mixtum* Condé, 1945] and two species of Diplura [*Campodea (Paurocampa) suensoni* Tuxen, 1930 and *Campodea (C.) silvestrii* Bagnall, 1918] were established in the 84 years lasting primary succession on the chemically loaded heaps at Petrovice u Karviné.

Protura occurred in the younger succession stages (since the 15 years old succession stage) sporadically in low densities of 100 - 700 ind. m^{-2} and were represented only by A. *traegardhi E. gramineum*, *E. mixtum* and *G. gracilis* (Fig. 4). These species were present in the samples up to the most developed 84 years old stage. They reached the highest densities of 4 200 - 10 200 ind. m^{-2} in the 74 and 84 years old stages. On the successively retarded dry grassland enclave of the 60 years old stage, *Proturentomon* cf. *noseki* became a regular inhabitant. Most abundant and diversified was the community of Protura in the 74 years stage with four species reaching a density of 5 400 – 10 200 ind. m^{-2} in total. The former colonizers were joined by a second dominant species, i.e. *Acerentulus exiguus*, reaching even higher density than *A. traegardhi* (Fig. 4).

Diplura entered the succession in the stage of invading grass tufts on the 20 years old heap (Fig. 4). Two species were recorded at this early stage of succession – *Campodea suensoni* and *C. silvestrii*. Both were represented in very low densities (100 - 400 ind.m^{-2}). *C. silvestrii* was no more recorded in the older stages of succession whereas *C. suensoni*, reaching only low densities of 100 to 500 ind. m^{-2}, became a regular member of the soil macrofauna community up to the oldest succession stages.

Table 1. Characteristics of samples B118, B122, D598 - D611 and E164 – E167. Substrate: 1 – red (Fe_2O_3), 2 – white ($CaCO_3$); Vegetation: 3 – mosses and lichens, 4 – mosses and grasses, 5 – trees, shrubs and grasses with herbs, 6 – succession stage of *Tilio-Quercetum* forest, 7 – retarded dry grassland succession stage; Humus form: 1 – microarthropod raw humus, 2 – raw humus-moder, 3 – moder-raw humus, 4 – moder; Humus depth: 2 – microscopic humus layer, 4 – 3-5cm humus layer, 5 – 5-10cm humus layer; Succession age (in years): R behind the year – retarded succession.

Sample No.	D598	D608	E164	D591	D589	E165	D590	D611	B118	B122	E166	E167
Substrate	1	1	1	1	1	1	2	2	2	2	2	2
Vegetation	3	4	4	4	5	5	7	6	7	6	6	7
Humus form	1	2	2	2	2	3	2	2	3	3	4	4
Humus depth	2	4	4	4	5	5	4	5	4	5	5	4
Succession age	15	20	20	25	25	49	60	60	74	74	84	84
Protura ind. m^{-2}	100	700	500	100	1000	2300	600	500	10200	5400	4200	700
Diplura ind. m^{-2}	-	200	400	100	500	100	-	100	100	200	-	-

Fig. 1. The succession was delayed on slopes and small substrate piles covered by terrestrial algae crusts, lichens and mosses. The succession became faster when the grass tufts entered into this processes. Red deposit heap in 1979.

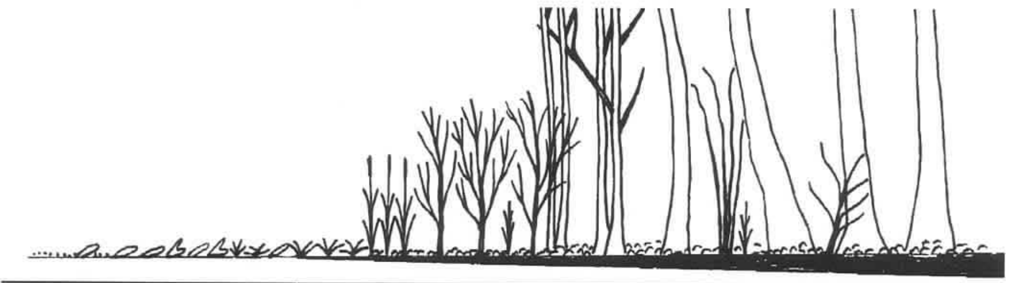
Fig. 2. The 15 years old red deposit with open moss community and two holes where soil samples were taken.

Fig. 3. The 25 years old succession stage in 1979.

Discussion

Protura and Diplura started to colonize both red and white deposit heaps 15 to 20 years later than Collembola and Acarina entering the succession at the early initial stages with a cover of soil algae and without a visible humus layer (Rusek, 2004). Protura entered the succession at the stage when the raw humus changed through the feeding activity of Collembola and Diptera larvae into a microarthropod raw humus form. Diplura needed a more advanced raw humus-moder form to enter the 20 years old stage. Larger Diplura did not find enough large air-filled free spaces in the earlier humus forms. The Protura community started with three species to develop progressively since the 20 years old succession stage. In the more developed 49 years old stage the proturan density increased to 2 300 ind. m^{-2}. Only since the 74 years and older forest stages with a moder humus form in the upper part of the humus horizon further Protura were able to enter the succession and form a more complex community.

The studied succession was retarded by the chemically loaded heap substrates (Rusek, 2004, 2005b). In the past we had studied a succession of xerothermic rendzina soils (Kubíková and Rusek, 1976). It differed substantially from the succession on the chemically loaded substrates of the heaps at Petrovice u Karviné. The succession on the heaps was developing slower and in different steps compared to the xerothermic rendzinas. We did not have exactly dated xerothermic rendzina soil succession series, but it was possible to establish an early stage with an open plant community (*Seseli – Festucetum duriusculae*) with a shallow microarthropod moder rendzina, more advances grassland communities with a mull-like rendzina and a climax thermophilous oak wood. We did not encounter a raw humus decomposition process and a raw humus form. The litter decomposition started there by the feeding activity of Collembola and Oribatida in the early stage of succession, and Diplopoda, Enchytraeidae and Lumbricidae entered the succession at the grassland stages. Diplopoda excrements were dominant in the moder humus form in the climax oak wood, as well as in the uppermost part of the mull-like humus form in the grassland soil. Diplopoda, Oniscidea, large Diptera larvae (e.g. Tipulidae, Bibionidae), as well as endogeic earthworms, did not enter the succession on the chemical factory heaps during the whole 84-year period of development. Ten species of Protura were established in the xerothermic rendzina succession series (Rusek, 1975b): *Eosentomon mixtum* Condé, 1945, *E. transitorium* Berlese, 1908, *E. delicatum* Gisin, 1945, *E. germanicum* Prell, 1912, *E. bohemicum* Rusek, 1966, *Eosentomon* sp., *Proturentomon noseki* Rusek, 1975, *P. pilosum* Rusek, 1975, *P. kubikovae* Rusek, 1975, and *Acerentomon tuxeni* Nosek, 1961. Three species occurred at the first stage of the xerothermic rendzina development: *E. mixtum, Eosentomon* sp. and *P. noseki*. During the winter period *E. mixtum* dominated, reaching a density of 1 800 ind. m^{-2}, whereas *Eosentomon* sp. and *P. noseki* were present in low densities of 100 ind. m^{-2}. In the grasslands two and six species of Protura with densities of 200 and 400 ind. m^{-2}, respectively, were found. Five species were recorded in the climax oak wood and their density reached up to 800 ind. m^{-2}. The



Succesion age (years)	15	20		25		49	60		74		84	
Acerentulus traeghardi	1	5	-	1	10	1	2	3	38	16	26	-
Acerentulus exiguus	-	-	-	-	-	-	-	-	51	37	16	-
Proturentomon cf. *noseki*	-	-	-	-	-	-	1	-	4	-	-	7
Gracilentulus gracilis	-	2	2	-	-	5	2	-	-	-	-	-
Eosentomon gramineum	-	-	2	-	-	17	1	2	9	1	-	-
Eosentomon mixtum	-	-	1	-	-	-	-	-	-	-	-	-
Campodea suensoni	-	1	4	1	5	1	-	1	1	2	-	-
Campodea silvestrii	-	1	-	-	-	-	-	-	-	-	-	-

Fig. 4. Density of Protura and Diplura species (in individuals per 100 cm^2) in different succession stages.

proturan communities in the successive rendzina soils started to form and to be established earlier in the succession, and they were much more diversified than in the retarded succession on the heap substrates.

Diplura did not find sufficiently suitable conditions for a second species even in the most developed 84 years old succession stage. This was probably due to the insufficiently thick moder humus layer as could be deduced from the succession on the brown coal spoil heaps in Germany, where *Campodea chionea* was able to co-exist with *C. fragilis* in more developed soils (Bode, 1973). The raw humus decomposition processes are retarded in the lower horizons (7.5 - 9 cm). This is probably a reason why *C. silvestrii*, already recorded in the 15 years old stage, could not live together with *C. suensoni* even in the most advanced succession stages.

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References

Bode, E., 1973. Beitrag zu den Erscheinungen einer Sukzession der terricolen Zoozönose auf Rekultivierungsflächen. Dissertation (Dr. rer. nat.), Naturwissensch. Fak. Tech. Univ. Carolo-Wilhelmina, Braunschweig, 114 pp.

Bode, E., 1975. Pedozoologische Sukzessionsuntersuchungen auf Rekultivierungsflächen des Braunkohlentagebaues. Pedobiologia, 15: 284-289

Hüther, W., 1959. Zur Ernährung der Pauropoden. Naturwiss., 46: 563-564

Kubíková, J., Rusek, J., 1976. Development of xerothermic rendzinas. A study in ecology and microstructure. Rozpravy ČSAV, řada matematických a přírodních věd, 86, Academia, Praha, 86, 8: 1-78

Rusek, J., 1975a. Eine Präparationstechnik für Springschwänze und ähnliche Gliederfüsser. Mikrokosmos, 65: 378-381

Rusek, J., 1975b. Zur Taxonomie und Synökologie der Gattung *Proturentomon* Silvestri (Protura). Věstník Československé Společnosti Zool., 39: 279-292

Rusek, J., 2004. Collembola succession on deposits from a chemical factory. Pedobiologia, 48: 519-525

Rusek, J., 2005a. Pauropoda and Symphyla succession on deposits from a chemical factory. Myriapodologica Czecho-Slovaca, 2: (in press)

Rusek, J., 2005b. Soil microstructure development during succession on chemical factory heaps. Europ. J. Soil Biol. (in press)

Sturm, H., 1959. Die Nahrung der Proturen. Beobachtungen an *Acerentomon doderoi* Silv. und *Eosentomon transitorium*. Berl. Naturwiss., 46: 90-91